Cold Rydberg atoms for quantum computation

Other

COLD RYDBERG ATOMS FOR QUANTUM COMPUTATION

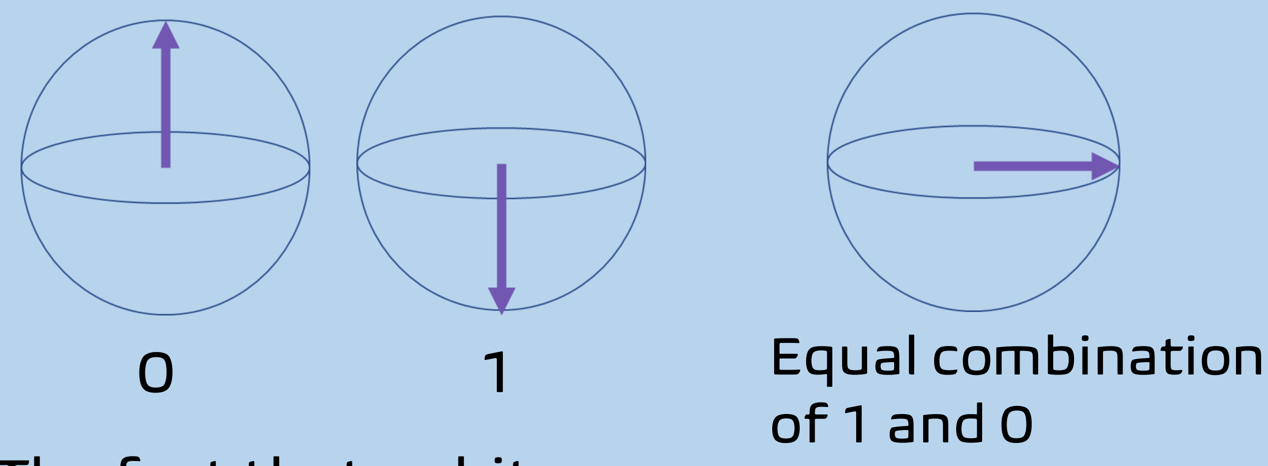
1. QUANTUM COMPUTING

Quantum computing is fundamentally different from classical computing, since it is based on the principles of quantum rather than classical physics. This makes available new algorithms that make it possible to solve problems have previously been unsolvable. It has the potential to revolutionise many fields, including pharmaceuticals and materials science by enabling complex chemicals to be modelled. There are a several methods being investigated for implementing quantum computing (superconductors, ions, photons to name a few). Here we are looking at neutral atoms.

2. QUBITS

In classical computers, information is encoded as a string of 0s and 1s know as bits. In quantum computers, the quantum bits (or qubits) can be in some combination of 0 and 1 at the same time (a superposition). We can depict qubits using a sphere representation.

BITS: QUBIT:



The fact that qubits can exist in more than one state at the same time means that they can store a lot more data than bits, however this information can only be accessed by repeated measurement of the similar qubits.

3. QUANTUM GATES

In classical computers, information is processed using logic gates, whose outputs depend on the inputs. The quantum analog is very similar, except that the input qubits can be in superposition states (more than one state simultaneously) and the same is true of the outputs. The table below shows the truth table for the CNOT gate. This is a two-qubit gate, where the state of qubit one determines what happens to qubit

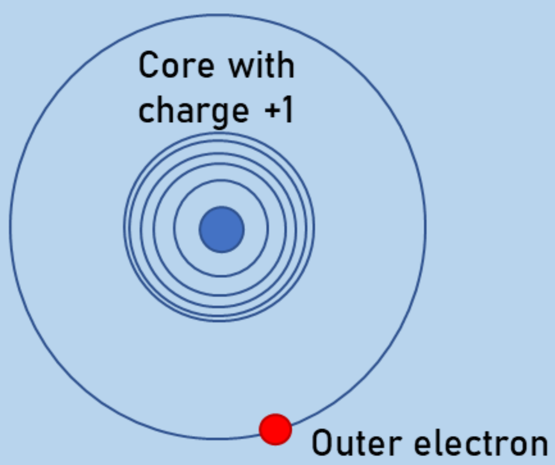
INPUTS

Qubit 1	Qubit 2	Qubit 1	Qubit 2
0	0	0	0
0	1	0	1
1	0	1	1
1	1	1	0

OUTPUTS

4. RYDBERG ATOMS & THE BLOCKADE

Rydberg atoms are atoms (often alkali metals) which are excited to a very high energy level n> 15. These atoms are very large, have surprisingly long lifetimes and interact strongly with surrounding atoms. If one atom in a sample is excited to the Rydberg state, any atoms within a certain distance of it cannot also be excited to the Rydberg state. This is because the strong interactions of the Rydberg atom with the surrounding atoms shifts their energy levels.



Rydberg atom: Alkali Metal

5. NEUTRAL ATOM QC

Neutral atoms have great potential for quantum computing because they offer long lasting atomic states in which to encode qubits. The interactions between the atoms can be controlled and activated using lasers. These qubits are inherently identical and are well suited to being scaled up to large qubit numbers, using arrays of laser traps. The states of the qubits can be measured precisely by looking at the light re-emitted by the qubits (fluorescence).

6. MY PROJECT

I am investigating the strong quantum correlations between cold atoms when they are excited to the Rydberg state and the effect this has on a particular quantum phenomenon. This work will inform my next task of implementing a C-NOT gate with cold atoms in laser traps, using a scheme which uses Rydberg interactions to control how the atoms interact with the laser beams.

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